Understanding Night Vision Generations

A Technical Reference Guide to Image Intensifier Tubes, Generation Differences, and Specification Datasheets

Compiled by the Superior Tactical Editorial Team

Superior Tactical LLC · Burleson, Texas

First Published: May 2026 · Revision 1.0

Abstract. This reference guide explains the technical and historical differences between night vision device generations, the operating principles of image intensifier tubes, and the specifications listed on tube datasheets — including Figure of Merit (FOM), Signal-to-Noise Ratio (SNR), photocathode sensitivity, and resolution. It is intended for buyers, technicians, military and law enforcement personnel, and journalists or researchers seeking a neutral overview of consumer and professional night vision technology.

Contents

1. Introduction	3
2. A Brief History of Night Vision Technology	3
3. How Image Intensifier Tubes Work	4
4. Generation Differences	5
4.1 Generation 0 (1930s–1940s)	5
4.2 Generation 1 (1960s)	6
4.3 Generation 2 and Generation 2+	6
4.4 Generation 3 and Generation 3+	6
4.5 Generation 4 (Filmless / Thin-Film)	7
4.6 Digital Night Vision	7
5. Reading a Tube Datasheet	7
5.1 Figure of Merit (FOM)	8
5.2 Signal-to-Noise Ratio	8
5.3 Resolution (lp/mm)	8
5.4 Photocathode Sensitivity	8
5.5 Halo	9
5.6 Equivalent Background Illumination	9
6. White Phosphor vs Green Phosphor	9
7. Auto-Gating	10
8. Civilian, Law Enforcement, and Military Considerations	10
9. Glossary	11
10. References	12

© 2026 Superior Tactical LLC — superiortac.com

1. Introduction

Night vision technology has evolved across more than eight decades from bulky active-infrared systems mounted on military vehicles to lightweight head-borne devices that civilians can purchase commercially. The technology behind a modern night vision monocular — the image intensifier tube — amplifies the small amount of ambient light present in nearly all natural outdoor environments and produces a real-time, electronically-rendered image bright enough for the human eye to use for navigation, observation, and target identification.

This reference document explains the principles behind image intensifier tubes, the historical and technical differences between the major generations of night vision devices (Generation 1 through Generation 4 and modern digital systems), and how to interpret the specifications listed on a tube datasheet. The intended audience includes buyers evaluating night vision purchases, technicians servicing equipment, personnel deploying night vision in operational contexts, and writers or researchers requiring a neutral technical overview.

All information in this guide is drawn from publicly available technical literature, manufacturer specification sheets, U.S. military procurement documents, and peer-reviewed sources where applicable. References are provided in section 10.

2. A Brief History of Night Vision Technology

The pursuit of practical night vision predates electronic image intensifiers. Early infrared photography in the 1930s demonstrated that light invisible to the human eye — in the near-infrared band — could be captured by appropriately sensitized photographic plates. Translating that principle into a real-time imaging device required two parallel developments: a photocathode capable of converting incoming photons into electrons, and a phosphor screen capable of converting those electrons back into visible light.

2.1 World War II and Active-Infrared Systems

The first deployable night vision devices appeared during the Second World War. Both German and American forces fielded active-infrared systems — sometimes called “sniperscopes” — that paired an infrared spotlight with a photocathode-based viewer sensitive to that wavelength. These systems were heavy, fragile, and required the user to project an infrared light onto the target, creating a tactical liability if the enemy possessed a similar viewer. The German *Vampir* system mounted on the Sturmgewehr 44 and the American M1/M2 sniperscope used on M3 carbines are the best-known examples.

© 2026 Superior Tactical LLC — superiortac.com

2.2 Vietnam and the First Passive Tubes

By the Vietnam War, U.S. forces had begun fielding the first passive image intensifier tubes — later retroactively classified as Generation 0 and Generation 1 — that did not require an external infrared illuminator to function in starlight or moonlight. The AN/PVS-2 “Starlight Scope” was the most widely deployed Gen 1 device of the era. These tubes were physically large, with cascade tubes stacked end-to-end to achieve sufficient gain, and produced significant image distortion at the edges.

2.3 The Microchannel Plate and the Move to Generation 2

The introduction of the microchannel plate (MCP) in the late 1960s and early 1970s enabled the shift to Generation 2. An MCP is a thin glass wafer perforated with millions of microscopic channels; each channel behaves as a continuous-dynode electron multiplier. By placing an MCP between the photocathode and the phosphor screen, a single tube could achieve the same electron amplification that previously required stacked cascade tubes — producing a brighter image in a much smaller, more rugged housing.

2.4 Gallium Arsenide and Generation 3

Generation 3, introduced in the early 1980s, was defined primarily by the use of a gallium arsenide (GaAs) photocathode in place of the multialkali photocathode used in Generation 2. The GaAs photocathode is substantially more sensitive in the near-infrared portion of the spectrum — the wavelengths most prevalent in starlight and atmospheric airglow — producing brighter images under low-light conditions than Generation 2 tubes. The U.S. Army adopted Generation 3 tubes for the AN/PVS-7 goggle and AN/PVS-14 monocular, and the technology has remained the dominant standard for U.S. military night vision through the present.

3. How Image Intensifier Tubes Work

An image intensifier tube performs three sequential operations on the light entering its objective lens: photon-to-electron conversion at the photocathode, electron multiplication through the microchannel plate, and electron-to-photon conversion at the phosphor screen. The resulting amplified image is viewed through an eyepiece lens.

3.1 The Photocathode

The photocathode is a thin layer of light-sensitive material deposited on the inside of the tube's objective-side window. When a photon of sufficient energy strikes the photocathode, the photoelectric effect causes the material to emit an electron. The wavelengths to which the photocathode responds — its *spectral response* — depend on the material composition. Generation 2 tubes typically use a multialkali (S-25)

© 2026 Superior Tactical LLC — superiortac.com

photocathode; Generation 3 tubes use gallium arsenide.

3.2 The Microchannel Plate (MCP)

Electrons emitted by the photocathode are accelerated by an electric field across a small vacuum gap and strike a microchannel plate. The MCP is a glass disc roughly 1 mm thick, perforated by 5–10 million microscopic channels each approximately 6–10 micrometers in diameter. An electron entering a channel collides with the channel wall, releasing additional secondary electrons; this cascade repeats along the channel length, producing thousands of output electrons for each input electron. Generation 3 tubes coat the MCP with an ion barrier film to extend tube life by preventing positive ions generated within the channels from accelerating back toward the GaAs photocathode and damaging it.

3.3 The Phosphor Screen

Electrons exiting the MCP are accelerated toward a phosphor-coated screen at the eyepiece end of the tube. When an electron strikes the phosphor, it deposits its kinetic energy and excites the phosphor to emit visible light at a wavelength characteristic of the phosphor compound. Traditional P22 (green) and modern P45 (white) phosphors are the most common, with commercial demand for white phosphor having grown substantially during the 2010s and 2020s. The pattern of light produced on the phosphor screen is a real-time, intensity-mapped representation of the original optical scene.

3.4 Power Supply and Auto-Gating

All image intensifier tubes require a high-voltage power supply — typically generating between 600 and 6,000 volts — from a low-voltage input (commonly a single AA, CR123, or proprietary battery). Modern tubes include an *auto-gating* circuit that rapidly pulses the tube's power on and off thousands of times per second, allowing the tube to operate safely in environments where bright light sources (vehicle headlights, muzzle flash, ambient daylight bleed) would otherwise damage the photocathode or wash out the image. Auto-gating is a defining feature of modern Gen 3+ tubes.

4. Generation Differences

The U.S. military classification system for night vision tubes was established to differentiate technological generations rather than performance per se. A late-production Generation 2+ tube may outperform an early Generation 3 tube in some specifications, despite the lower numerical generation. Buyers should evaluate individual tube specifications — FOM, SNR, resolution — rather than relying solely on generation labels.

4.1 Generation 0 (1930s–1940s)

© 2026 Superior Tactical LLC — superiortac.com

Generation 0 refers to the active-infrared sniperscopes deployed during World War II and immediately afterward. These devices required a co-mounted infrared spotlight to provide target illumination and used an early photocathode sensitive to near-infrared wavelengths. Image quality was poor, units were heavy and fragile, and operation required the user to broadcast infrared light, which a similarly equipped enemy could detect. Generation 0 systems are not in current military service.

4.2 Generation 1 (1960s)

Generation 1 introduced passive image intensification, eliminating the need for an active infrared illuminator. Gen 1 tubes use a multialkali (S-20) photocathode and electrostatic-focus electron acceleration; amplification was achieved by stacking multiple cascade tubes in series. The resulting devices were physically large, exhibited geometric distortion (especially at image edges), and produced visible “blooming” around bright light sources. The AN/PVS-2 Starlight Scope deployed in Vietnam is the canonical Generation 1 device. New Generation 1 tubes remain available in the consumer market at low price points but offer substantially less capability than Generation 2 or Generation 3 systems.

4.3 Generation 2 and Generation 2+

Generation 2 tubes incorporate a microchannel plate for electron amplification, producing significantly higher gain in a smaller package than the cascade-tube designs of Generation 1. Gen 2 photocathodes are typically multialkali (S-25), with peak spectral response in the visible portion of the spectrum. Generation 2+ refers to incremental improvements made during the 1990s and 2000s — primarily improved photocathode materials, better MCP characteristics, and tighter tube construction tolerances — that yielded measurable but not categorical improvements over baseline Generation 2.

Modern high-end Generation 2+ tubes manufactured by European producers (notably Photonis in France) achieve SNR figures and resolutions competitive with U.S.-manufactured Generation 3 tubes, while operating across a slightly different spectral response curve. Buyers should compare specific tube datasheets rather than assume generation labels indicate definitive performance ordering.

4.4 Generation 3 and Generation 3+

Generation 3 is defined by the use of a gallium arsenide (GaAs) photocathode in place of the multialkali photocathode used in earlier generations. The GaAs photocathode exhibits substantially higher sensitivity in the 600–900 nanometer range — the wavelengths predominant in starlight, moonlight, and atmospheric airglow — producing markedly brighter images in low-light conditions than Generation 2 tubes of comparable physical specification.

© 2026 Superior Tactical LLC — superiortac.com

Generation 3+ refers to refinements introduced over the operating life of the Generation 3 standard, including thin-film MCP ion barriers, auto-gating, improved photocathode sensitivity (frequently exceeding 1,800 microamperes per lumen in current production), and tighter tolerance on resolution and signal-to-noise ratio. The U.S. Army's OMNI procurement program has issued tubes from successive OMNI generations (OMNI VII, OMNI VIII, OMNI IX) that broadly correspond to incremental improvements in Generation 3+ specifications.

4.5 Generation 4 (Filmless / Thin-Film)

The term “Generation 4” was applied during the late 1990s to a filmless tube design that omitted the ion barrier film coated onto the MCP, with the goal of further increasing photocathode response by removing an additional barrier between incoming electrons and the amplifier. The filmless design produced higher SNR figures but proved to have shortened operating life under certain conditions. The U.S. Army subsequently revised its categorization, retiring the Gen 4 designation and reclassifying these tubes under the Generation 3 umbrella with thin-film or filmless variants.

Some manufacturers continue to use the term “Gen 4” in marketing literature for tubes with extremely thin or non-existent ion barriers, but the term has no formal U.S. military classification standing. Buyers encountering “Gen 4” designations should request the underlying tube datasheet specifications for objective comparison.

4.6 Digital Night Vision

Digital night vision uses a CMOS or CCD image sensor sensitive to low light and near-infrared wavelengths in place of the photocathode-MCP-phosphor stack of an analog tube. The digital signal is processed by an onboard computer and displayed on a small electronic screen viewed through the eyepiece. Digital systems offer image recording, color imaging in adequate light, integration with other digital systems, and lower per-unit cost than tube-based systems. Trade-offs include higher latency, lower performance under extreme low light, and battery life sensitivity to display brightness.

Recent developments in low-light CMOS sensors — notably the Sony STARVIS line and successor architectures — have closed the performance gap between digital and tube-based systems in moderate low-light conditions, although image intensifier tubes retain advantages in starlight-only conditions and in environments where minimal latency is operationally critical.

5. Reading a Tube Datasheet

Image intensifier tubes are sold and procured against documented performance specifications. A tube datasheet — sometimes called a “blue paper” or “data sheet” — lists the measured values for that specific serial-numbered tube. Tubes within a single

© 2026 Superior Tactical LLC — superiortac.com

production batch may exhibit measurable variation, and tube prices in the commercial market are commonly tied to the specific datasheet values for the tube being purchased.

5.1 Figure of Merit (FOM)

Figure of Merit is a composite specification calculated as the product of resolution (in line pairs per millimeter, lp/mm) and signal-to-noise ratio (SNR). FOM is widely used as a single-number summary of tube quality and is the most common specification cited by both military procurement and commercial sellers. The U.S. Department of Commerce imposes export controls on image intensifier tubes with FOM values above 1,600 (sometimes 1,400 or 2,000 depending on classification), making FOM not just a technical specification but also a regulatory threshold.

Typical FOM values: a baseline civilian-market Gen 3 tube may rate FOM 1,400–1,600; a high-end Gen 3+ tube delivered to U.S. military specification frequently exceeds 2,000; and exceptional high-end tubes (often called “cherry tubes” in the trade) may rate above 2,400.

5.2 Signal-to-Noise Ratio (SNR)

Signal-to-Noise Ratio is a measure of image clarity under low-light conditions. A higher SNR indicates a cleaner image with less visible “scintillation” (the random sparkle artifact characteristic of intensified images). SNR is measured at a standardized low-light input, with results expressed dimensionless. Modern Gen 3 tubes produced under U.S. military OMNI specifications commonly produce SNR values between 25 and 35; exceptional tubes may exceed 38.

5.3 Resolution (line pairs per millimeter)

Tube resolution is measured by imaging a standardized test target (typically the USAF 1951 resolution chart) at the photocathode and counting the finest line pair pattern that remains discernible at the phosphor output. The unit — line pairs per millimeter, lp/mm — expresses spatial detail directly at the tube and is independent of the optics fitted to the tube. Modern Gen 3 tubes typically resolve between 64 and 81 lp/mm, with exceptional tubes resolving 81 lp/mm or higher.

5.4 Photocathode Sensitivity

Photocathode sensitivity expresses the photocathode's efficiency at converting incoming photons into electrons, measured in microamperes per lumen (µA/lm). Higher sensitivity directly translates to a brighter output image at any given input light level. Generation 2 multialkali photocathodes typically rate 350–700 µA/lm; Generation 3 GaAs photocathodes typically rate 1,400–2,500 µA/lm.

© 2026 Superior Tactical LLC — superiortac.com

5.5 Halo

Halo is the bright ring or disc that appears around point light sources in an intensified image, caused by lateral electron drift between the photocathode and the MCP. Halo is measured in millimeters as the diameter of the visible halo around a standardized point source; smaller is better. Modern thin-film Gen 3+ tubes typically exhibit halo of 0.7–1.0 mm; older or filmless tubes may exhibit halo of 1.2 mm or more. In practical use, lower halo improves operator ability to identify objects and threats near bright lights such as vehicle headlights, streetlights, or muzzle flash.

5.6 Equivalent Background Illumination (EBI)

Equivalent Background Illumination measures the residual luminance produced by the tube even in complete darkness, expressed in lumens per square centimeter. EBI represents the noise floor of the tube; lower is better. Typical Gen 3 tubes rate EBI between 0.5 and 2.5 × 10^{-10} lm/cm^2. EBI is sensitive to ambient temperature; tubes warm to operating temperature produce higher EBI readings than cold-bench measurements.

Example Tube Datasheet

Specification	Measured Value	Acceptance Range
Resolution (lp/mm)	72	64 minimum
Signal-to-Noise Ratio	32.4	25 minimum
Figure of Merit (FOM)	2,333	1,600 minimum
Photocathode Sensitivity (µA/lm)	2,184	1,800 minimum
Halo (mm)	0.85	1.25 maximum
EBI (×10^{-10} lm/cm^2)	1.1	2.5 maximum
Phosphor	P45 (white)	—
Auto-Gating	Yes	Required
Photocathode Type	GaAs (Generation 3)	—

Figure 1. Representative datasheet for a high-performance Generation 3+ image intensifier tube manufactured to U.S. military OMNI specification. Acceptance ranges are illustrative.

6. White Phosphor vs Green Phosphor

© 2026 Superior Tactical LLC — superiortac.com

Image intensifier tubes have historically used a P22 phosphor that produces a green output image (peak emission near 545 nanometers), selected because the human eye's scotopic (low-light) response peaks near that wavelength. Beginning in the 2010s, manufacturers began offering tubes with a P45 phosphor producing a white-gray output image (broader spectral emission), which many operators report as more natural to the eye and less fatiguing during extended use.

From a pure photometric standpoint, green phosphor tubes deliver marginally more visible-light energy to the eye for a given electron input, because the phosphor emission aligns more closely with peak scotopic eye response. From a usability standpoint, white phosphor produces an image more analogous to an unaided low-light scene and reduces the temporary impairment of dark adaption that occurs when transitioning from intensified to unaided viewing. The choice between phosphors is generally a matter of operator preference and operational role.

7. Auto-Gating

Auto-gating is a feature of modern image intensifier tubes that rapidly cycles the tube's power supply on and off — typically at frequencies above 5 kilohertz — to limit the duty cycle during which the photocathode is exposed to high-intensity light. The feature serves three purposes: it allows the tube to operate in dynamic-light environments (such as urban areas with streetlights, vehicle headlights, or muzzle flash) without permanent damage to the photocathode; it preserves image quality by preventing saturation of the MCP; and it extends overall tube operating life.

Auto-gating is required for U.S. military procurement under current OMNI specifications and is universal in current commercial Gen 3 production. Older Gen 3 tubes manufactured before approximately 2005, and many low-end Gen 2 and Gen 1 tubes, do not include auto-gating; operating these tubes in environments with intermittent bright lights can degrade image quality and shorten useful tube life.

8. Civilian, Law Enforcement, and Military Considerations

8.1 U.S. Export Controls

Image intensifier tubes are classified under the U.S. Munitions List and the Export Administration Regulations, with FOM (Figure of Merit) thresholds determining export licensing requirements. Tubes with FOM values above the controlled threshold cannot be exported from the United States without a license issued by the Department of State or Department of Commerce. This creates a tiered commercial market in which the highest-performing tubes are typically only available to U.S. citizens, U.S. military, and

© 2026 Superior Tactical LLC — superiortac.com

approved domestic law enforcement agencies.

8.2 Mounting and Headborne Use

Image intensifier tubes are housed within monoculars (single-tube devices such as the AN/PVS-14) or binocular and quad-tube goggles (such as the AN/PVS-31, AN/PVS-15, and Ground Panoramic Night Vision Goggle). Headborne use requires a ballistic helmet with a dovetail shroud (such as the Wilcox or Norotos pattern) and a mount that interfaces between the shroud and the device. Helmet-mounted operation is standard for both military and civilian use; weapon-mounted operation, while possible, requires careful zeroing and is not common for general observation.

8.3 Battery and Operating Considerations

Most modern monocular image intensifier devices operate on a single AA or CR123 battery for 10–50 hours depending on auto-gating duty cycle and environmental conditions. Cold weather significantly reduces battery life, particularly for alkaline AA batteries; lithium AA or CR123 batteries are recommended for cold-weather use. Some devices accept auxiliary power from external battery packs via a remote cable port for extended-mission operation.

9. Glossary

Auto-Gating. A power-supply feature that rapidly pulses tube power on and off thousands of times per second to enable safe operation in dynamic light conditions.

EBI (Equivalent Background Illumination). The residual luminance produced by an image intensifier tube in complete darkness, representing the tube's noise floor.

FOM (Figure of Merit). A composite specification calculated as the product of resolution (lp/mm) and SNR; widely used as a single-number summary of tube quality.

Halo. The bright ring or disc that appears around point light sources in an intensified image, measured in millimeters.

Image Intensifier Tube. The optoelectronic component of a night vision device that converts incoming light to electrons, amplifies the electron stream, and converts the amplified stream back to visible light on a phosphor screen.

Microchannel Plate (MCP). A thin glass disc perforated by millions of microscopic channels, each acting as a continuous-dynode electron multiplier; introduced with Generation 2 tubes.

OMNI. A series of U.S. Army procurement specifications (OMNI I through OMNI IX and beyond) defining performance requirements for image intensifier tubes purchased for military use.

© 2026 Superior Tactical LLC — superiortac.com

Photocathode. The light-sensitive layer at the input end of an image intensifier tube that converts incoming photons to electrons via the photoelectric effect.

Phosphor. The compound coating the screen at the eyepiece end of an image intensifier tube; converts electrons back into visible light. P22 produces green output; P45 produces white output.

SNR (Signal-to-Noise Ratio). A dimensionless measure of image clarity at a standardized low-light input; higher values indicate cleaner images.

10. References

The information in this guide is drawn from the following publicly available sources. Readers are encouraged to consult original sources for technical details and current specifications.

[1] U.S. Army Research, Development, and Engineering Command (RDECOM). *OMNI Procurement Specification for Image Intensifier Tubes.* Updated periodically; available through U.S. Army Communications-Electronics Command (CECOM).

[2] U.S. Department of Commerce, Bureau of Industry and Security. *Export Administration Regulations (EAR), Commerce Control List, Category 6: Sensors and Lasers.* Available at bis.doc.gov.

[3] U.S. Department of State, Directorate of Defense Trade Controls. *International Traffic in Arms Regulations (ITAR), United States Munitions List, Category XII: Fire Control, Laser, Imaging, and Guidance Equipment.* Available at pmddtc.state.gov.

[4] Csorba, I. P. (1985). *Image Tubes.* Howard W. Sams & Co. ISBN 0-672-22023-7. Foundational reference text on image intensifier tube design and operation.

[5] L3Harris Technologies. *Image Intensifier Tube Specification Sheets.* Manufacturer product literature, available at l3harris.com.

[6] Photonis. *4G High-Performance Image Intensifier Tube Technical Datasheets.* Manufacturer product literature, available at photonis.com.

[7] Elbit Systems of America. *F5050 and F9400 Image Intensifier Tube Specification Sheets.* Manufacturer product literature.

[8] Holst, G. C., & Lomheim, T. S. (2011). *CMOS/CCD Sensors and Camera Systems* (2nd ed.). SPIE Press. ISBN 978-0819486530.

[9] Kalafut, J. (2002). “Generation 4 Image Intensifier: Filmless and Auto-Gated.” *Proceedings of SPIE*, Vol. 4796.

[10] U.S. Army Aviation and Missile Research, Development, and Engineering Center. *Night Vision Devices: Operator's Manual for AN/PVS-14.* TM 11-5855-306-10.

[11] Howe, J. D. (1990). *Electro-Optical Imaging System Performance.* SPIE Press, in association with JCD Publishing. Reference text on low-light imaging system metrics.

[12] Pollehn, H. K. (1988). “Performance and Reliability of Third-Generation Image Intensifiers.” *Advances in Electronics and Electron Physics*, Vol. 71, pp. 1–34.

© 2026 Superior Tactical LLC — superiortac.com

About This Guide. This reference document was prepared by the Superior Tactical editorial team in May 2026. Superior Tactical LLC is a Texas-based retailer of commercial night vision and tactical optics for civilian, law enforcement, and military customers. This guide is provided for educational and reference purposes; no endorsement of any specific manufacturer or product is implied. Comments, corrections, and citation requests may be directed to the publisher at superiortac.com.

© 2026 Superior Tactical LLC — superiortac.com